Thermal Operations In Food Process Engineering: Theory And Applications
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Lecture - 46
Heat Exchangers (Contd.)

Good morning. We are handling with Heat Exchangers and we said that, there are different types of heat exchangers which are in used in industry in nature and also we said that heat exchangers are those who where you are exchanging heat, but as such everywhere it is being exchanged whereas, there is a temperature difference there is a exchange of heat. So, in that case everything is not said to be heat exchanger, the reason we had already said in the previous class, 'right'.

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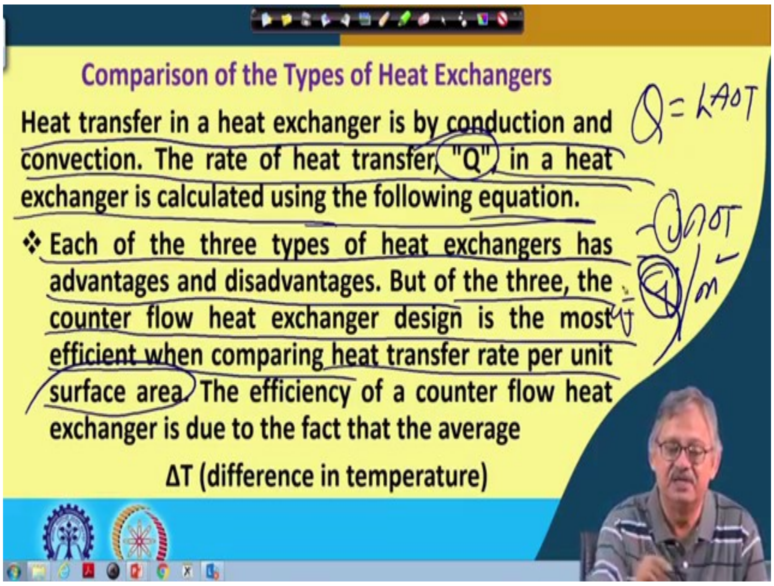

Now, we were comparing the types of heat exchangers and if in this continuation class of heat exchangers in the 46 class. We now come to that we are comparing that types of heat exchangers, 'right'. So, heat transfer in heat exchangers is normally by conduction and also it can be by convection, 'right'.

So, if it is by conduction and convection, the rate of heat transfer normally again the radiation heat is more or less encountered in this type of heat exchangers, 'right'? I am not saying radiation is not there in the heat exchangers are not at all, but normally which we come across there these heat exchangers are the mode of heat transfer is primarily by conduction and also by convection, ‘right’.

So, if Q is the heat transfer and this is in an heat exchanger this is usually calculated with some equations which we will be we have already said that Q = U A ΔT. Or if it is not U, U is the overall heat transfer coefficient sometime we will come into that or it can also be h A ΔT, ‘right’, this is simply from the Newton’s law of cooling.

Now, each of the three types of heat exchangers which we have already said has advantages and also disadvantages. But of the these three the counter flow heat exchanger design is the most efficient when comparing with other type of heat transfer or comparing heat transfer rate per unit surface area; that is q over m^2 or rather this q capital Q over m^2 which is equal to small q, ‘right’.

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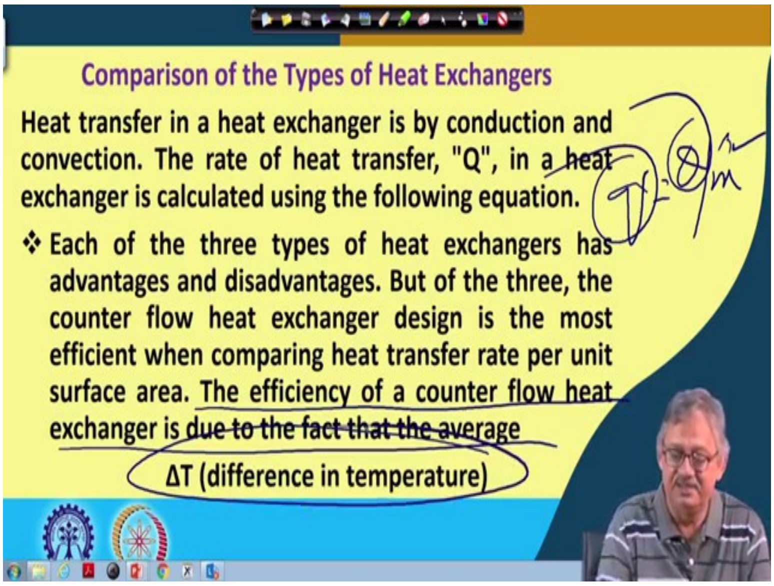

So, this small q is capital Q over m^2 by default we said that generally this is followed that capital Q is the rate and this is the flow heat flux ok.

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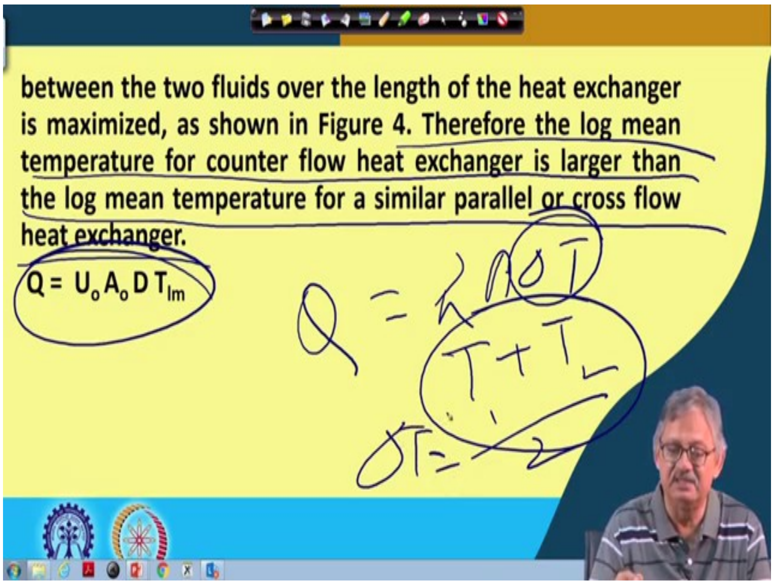

So, the efficiency of a counter flow heat exchanger is due to the fact that, the ΔT, that is the difference in temperature. This ΔT that difference in temperature between the two fluids, 'right', over the length of the heat exchanger is maximized, 'right'. Now, which we have already shown, 'right', sometimes we will change it and show you that when we drew it.

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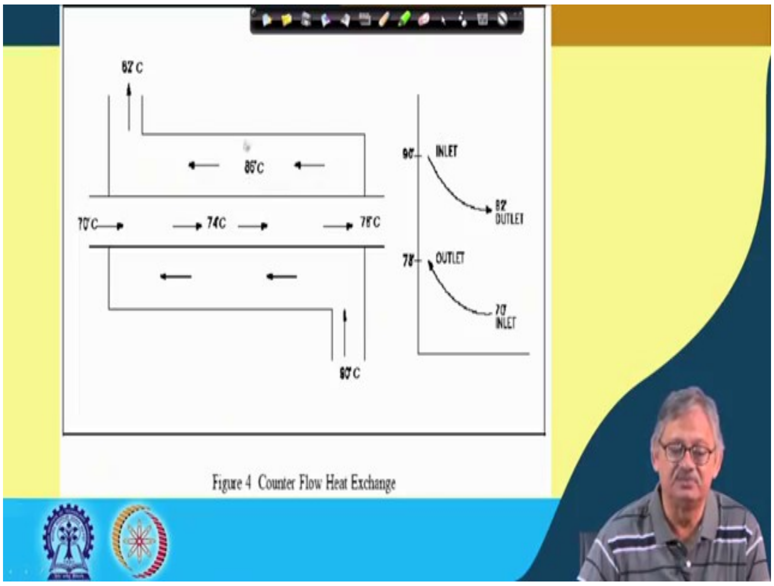

Somewhere this weight came up, so some time will show you there ok.

So, in this we have shown that counter current heat exchange and that the log mean temperature for counter current. The log mean temperature difference for the counter current, 'right' for the counter flow or counter current heat exchanger is larger than the log mean temperature for a similar parallel or cross flow heat exchanger. This also we will show and we said the one Q which is we had said just now h A ΔT, but since the difference between them is more or less significant.

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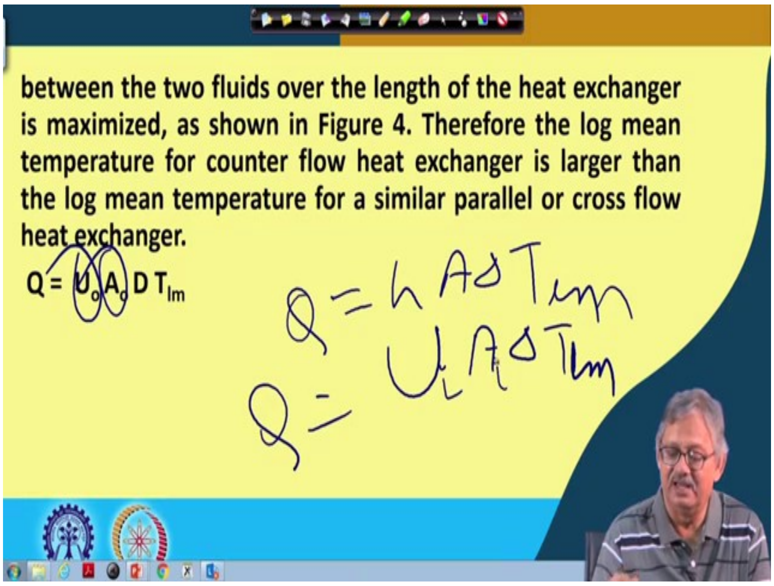

So, the average ΔT is T + T_1 + T_2 / 2 this is the average this average is not used, rather log mean temperature difference; that is q = h A ΔT_{lm} or Q = U A ΔT. Now this you can be U_o based on outside area also based on outside, this also can be U_i A_i depending on the situation, 'right'.

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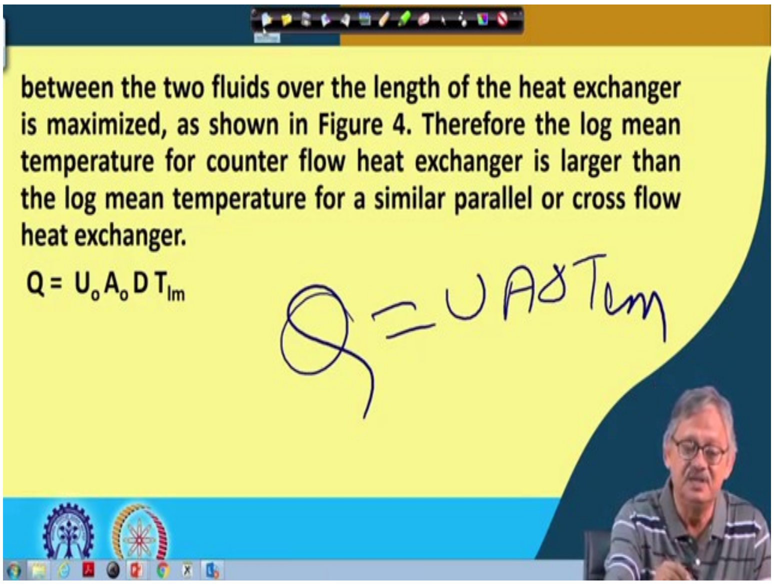

So, that is why I simply wrote that $Q = U A \Delta T_{lm}$, 'right', this is generally followed.

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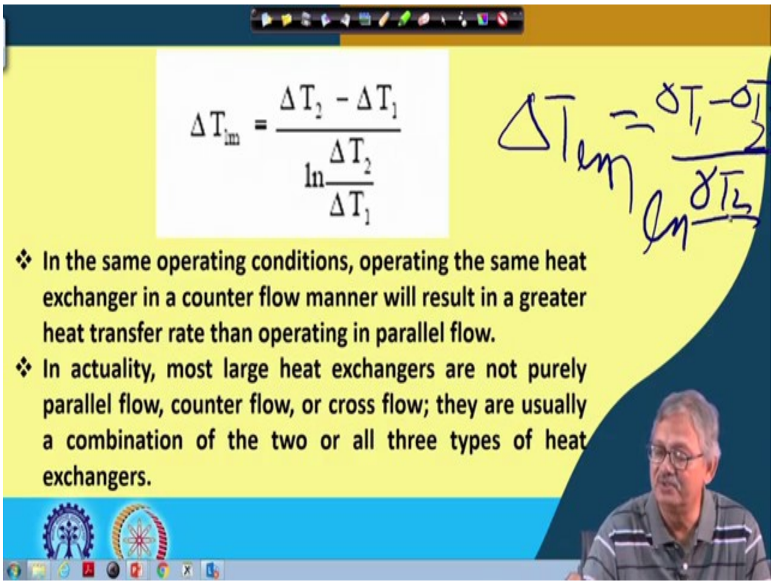

Now if we look at what is ΔT_{lm}, 'right'? So, ΔT_{lm} is the log mean temperature difference, which we can write as ΔT_{lm} is equal to rather lm is equal to $(\Delta T_1 - \Delta T_2)$ / ln $(\Delta T_2$/ or if it is $\Delta T_1 - \Delta T_2$.

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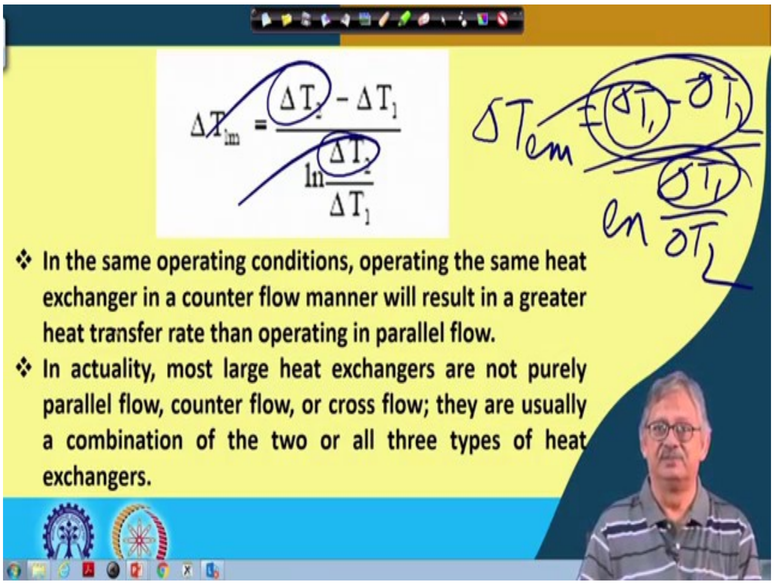

Then it should be, it should be ΔT_{lm} we are saying $(\Delta T_1 - \Delta T_2) / \ln (\Delta T_1 / \Delta T_2)$. The thing is that if I start with 1 then, this numerator also 1; if I start with 2, then this numerator is also 2. So, this only we have to keep in mind, 'right'. So, and what is that ΔT_1 and ΔT_2 that we will tell depending on the flow, 'right'.

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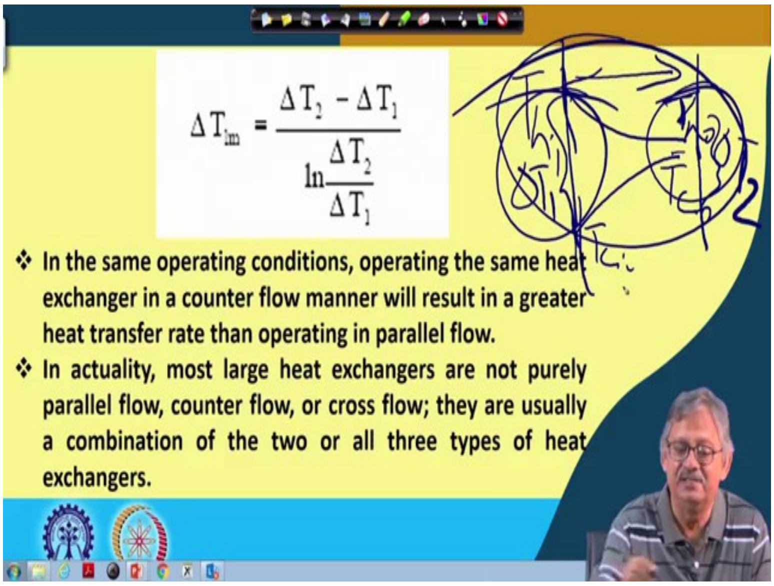

You if you remember, we had said that this was for co-current, 'right'. So, if it was hot inlet and it is if it is hot outlet T rather T hot outlet. If it is for T cold inlet, if it is for T cold outlet then you can define these ΔT_1 and ΔT_2 with this for this is the ΔT, you can tell it to 1 you can tell it 2 and this is the ΔT. Again you can tell it to 1 or you can tell it 2 whatever you the way you like, but this is the ΔT this is the ΔT, 'right'.

This is not that the ΔT is between this and that or between this and that, 'right'. So, this ΔT is are to be properly defined then you have the solution, 'right'. Now in the same operating conditions, operating the same heat exchanger in a counter flow manner will result in a greater heat transfer rate than operating in a parallel flow. In actually most large heat exchangers are not purely parallel flow, counter flow or cross flow, 'right'.

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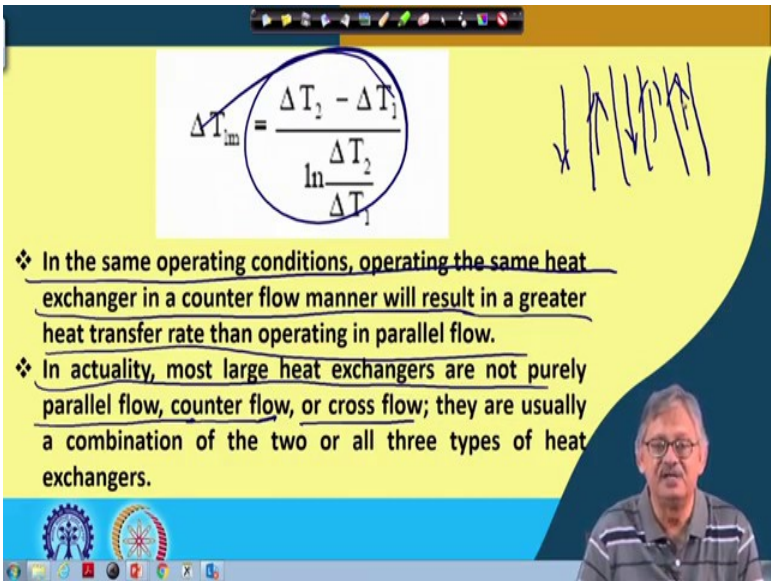

This is the fact that actually which I had also said in the plate heat exchanger if you remember, 'right' where we had plate heat exchanger and the flow are were like this, 'right'. So, we said depending on the flow pattern, you have co currency or counter currency, 'right'. They are usually a combination of the two or all of them that all three of them, 'right', ok, if that be true.

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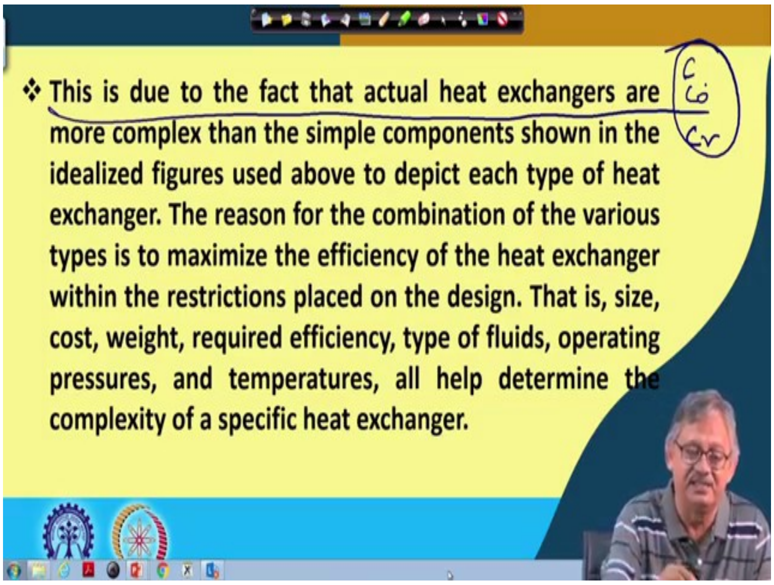

Now let us come into what we mean by Δ or some more some more information are there regarding the comparison; that why this was that why ΔT I mean that counter current had the maximum efficiency this is due to the fact that. In actual heat oh no this is not that why it is that, we said that in actual case only counter current or only co current or only cross flow these are not actually happening.

In actual case it may be combination of two or all three of them are there, ‘right’ and why that that is what we are saying here; that this is due to the fact that the actual heat exchangers are more complex than the simple components as we have already shown, ‘right’ and they are called idealized figures, ‘right’. And to depict each type of heat exchanger ok, that counter current co current whatever we had said so there it is that more or less idealized, ‘right’.

The reason for the combination of the various types is to maximize the efficiency of the heat exchanger within the restrictions placed on the design. That is size, cost, weight, required efficiency, type of fluids, operating pressures and temperatures all help to determine the complexity of this specific heat exchanger, ‘right’ all help to determine the complexity of a specific heat exchanger, ‘right’.

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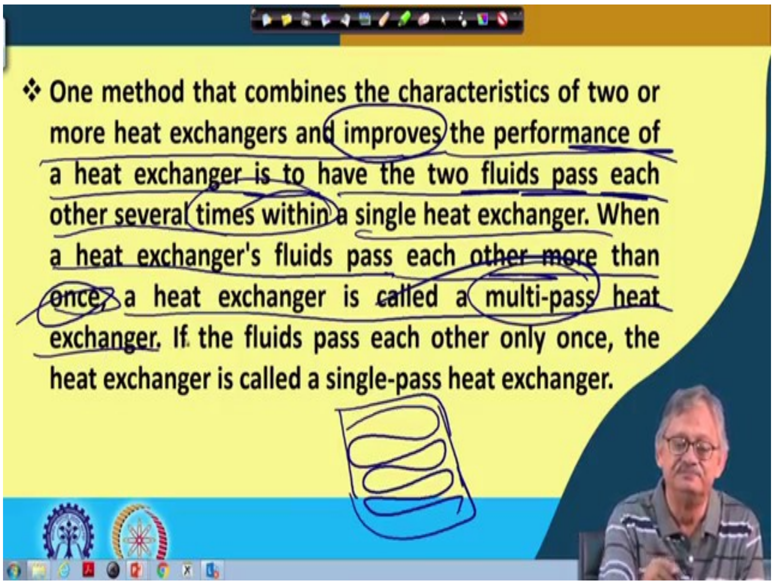

So, one method that combines the characteristics of two or more, heat exchangers and improves the performance of our heat exchanger is to have the two fluids pass each other several times within a single heat exchanger, 'right'. So, this is how the complexity can be introduced that, one of the methods to combine the characteristics of two or more heat exchangers and improves the performance of a heat exchanger is to have the two fluids pass each other several times within a single heat exchanger.

When a heat exchangers fluids pass each other more than once, a heat exchanger is called a multi pass, 'right'. So, we have a heat exchanger, if a fluid is passing multiple times through this, 'right' and maybe this is the shell and these are the tubes, 'right'. So, in that case it can be said that the actual thing is, the fluid is coming in contact multi times in different directions, 'right' and that is what we call multi pass heat exchanger, 'right'. So, if the fluids pass each other only once the heat exchanger is called a single pass heat exchanger which we have till now shown, 'right'.

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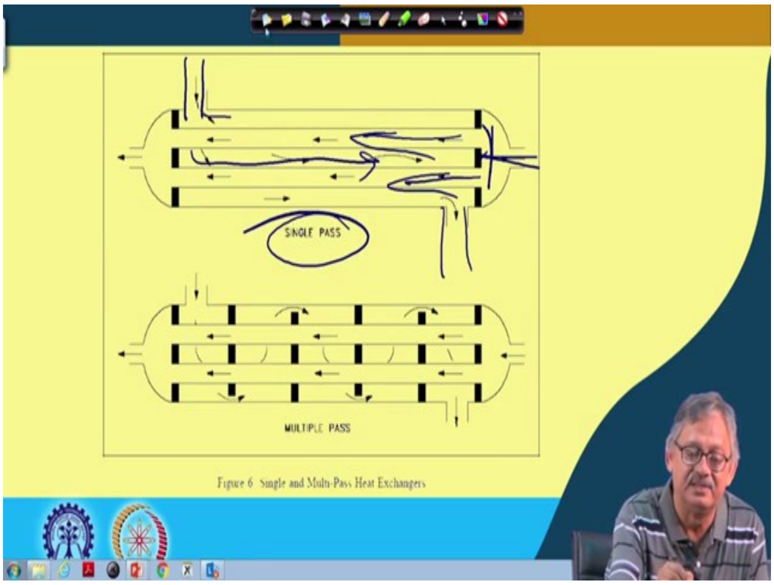

So, if we look at how it looks like, it looks like this, ‘right’ it looks like this that a single pass is you see the fluid is coming through this, ‘right’ and going out through this one fluid, so it is coming and going out through this. And the other fluid which is coming through this, ‘right’ just after coming over here it is getting distributed, one it is going through this another it is going through this, ‘right’. And this is this is the outer and the inner one is coming like that. Let us remove them, so inner one is coming like that, ‘right’.

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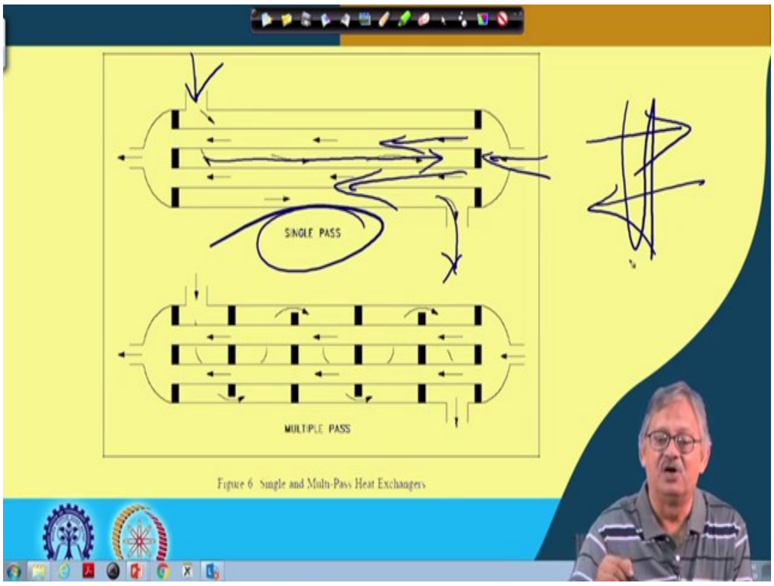

So, this way it is coming and going out this was the entry and the other two they are going this way and this way. So, basically we have one fluid is flowing this way and another fluid is flowing this way. So, this is called single pass because, they are coming across only once, 'right' in one direction whereas, had it been like this that we said earlier also if baffles are used for changing the directions, 'right'.

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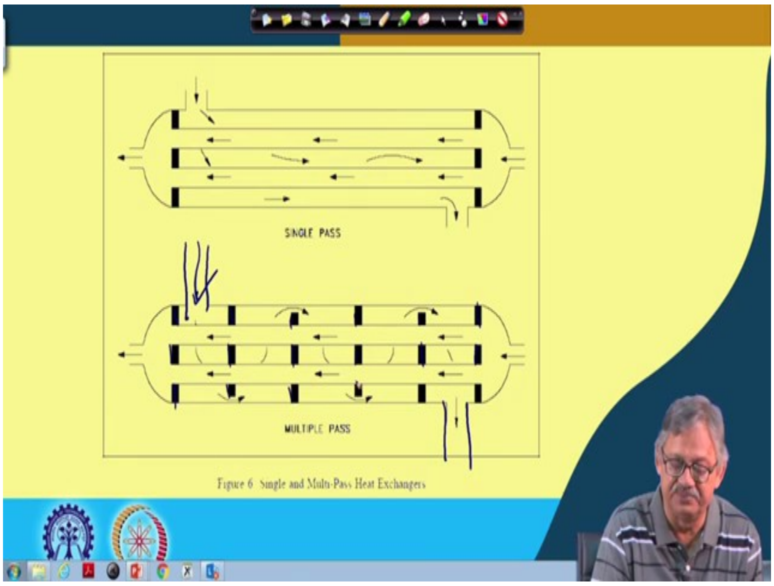

So, in that case we have one fluid entering through this and exiting to this, 'right', this is that fluid ok. And the design is such that we have placed baffles in different ways, 'right', we have placed baffles in different ways like this we have placed the baffles, 'right'.

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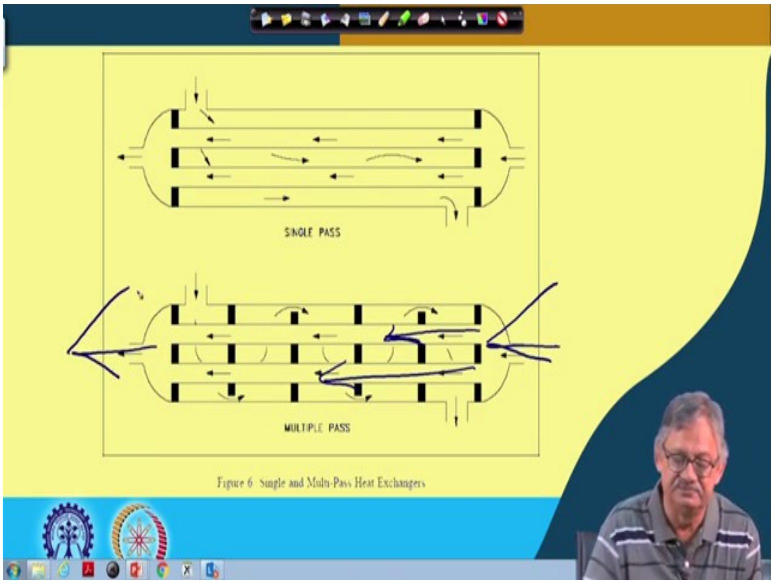

So, if the baffles are placed and the other fluid is moving this way, 'right' the other fluid is moving this way. So, it is coming like this and I usual and it is also going like that going in this way, 'right'.

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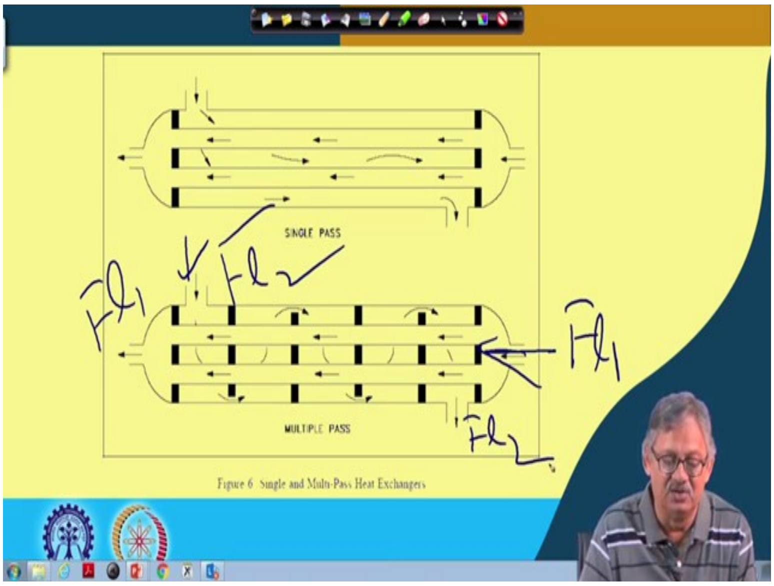

But with this we have with this fluid say fluid one we have no directional change, 'right', but with fluid 2, which is coming from there and exiting from here we have a lot of changes due to the baffle, 'right'.

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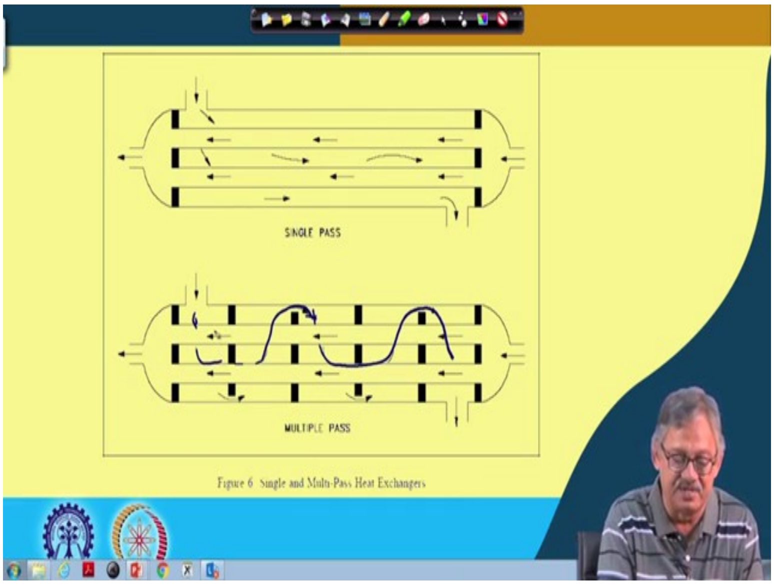

So, when it came as it is it is coming like this coming going like this again coming like this going like this coming like this going like this, 'right'.

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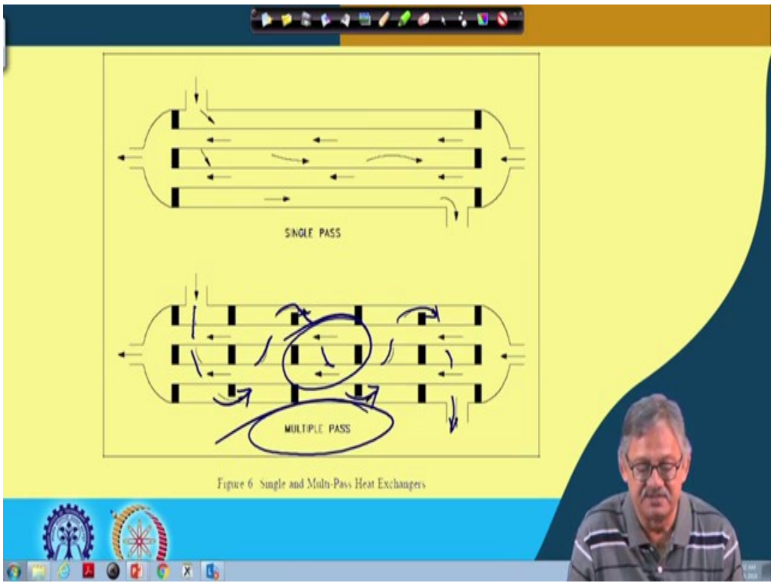

So, similarly that actually should have been it should have been like that, it should have been coming like this way, going like this way and again coming like this way going like this way and again coming like this and exiting, 'right'. Then you see how many times they are coming across with this as many times they are coming across so this is called multi pass, ‘right’, so this is called multi pass ok. And; obviously, the direction of the flow or how many parallel how many counter diodes is to be determined.

But here we are not determining because this is not the one where we are doing any problem with this; this is just to identify how a single pass and a multi pass are looking at, ‘right’ how a single pass and multi pass are looking at, ‘right’? So, this is a single and multi pass heat exchanger which we have just shown and explained how it is operating, ‘right’.

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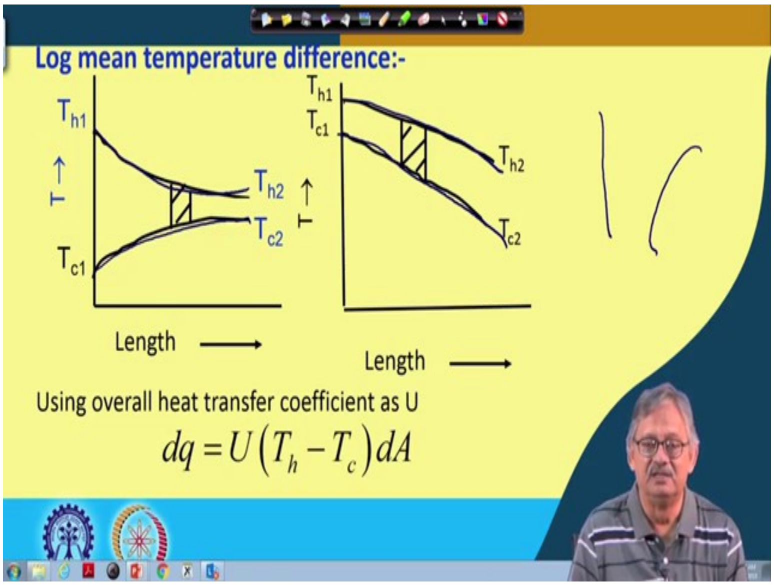

Then, we come back to the log mean temperature difference, ‘right’. In many cases if it is a curvilinear, since drawing with this mouse was a or is very difficult unless it is a straight line, ‘right’; if it is a curvilinear so, there could be a little not absolutely book type figure, but doesnt matter it is understandable.

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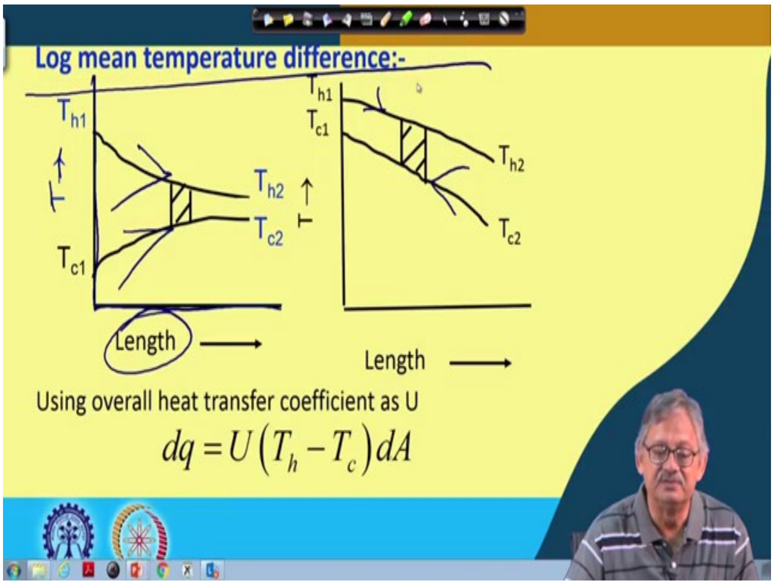

So, here we forgot to give you this direction, 'right', so this is the direction and in this case this is the direction, 'right'. So, you see the log mean temperature difference which were discussing discussing and here we have a plot of temperature versus length of the heat exchanger, 'right', the just now which we had shown you that length of the heat exchanger which is this, 'right'.

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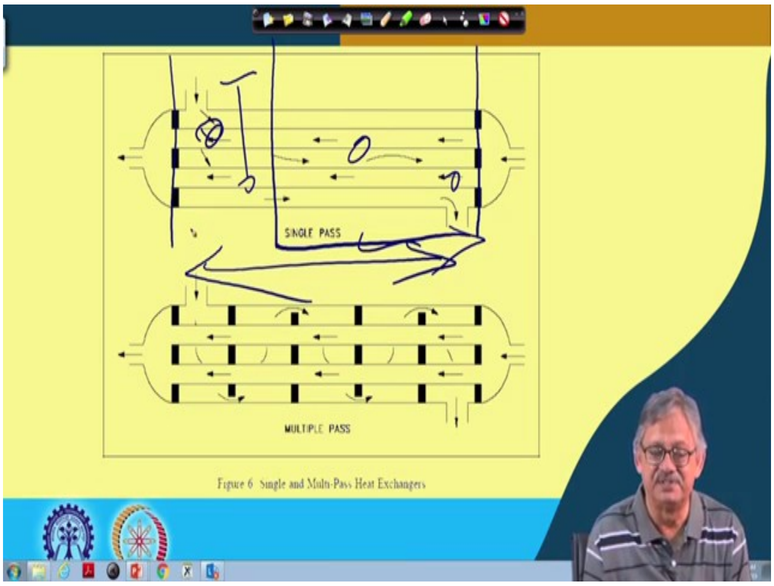

So, this length of the heat exchanger means that how much heat is getting exchanged in this length, 'right'? So, we have a plot of this temperature versus this heat exchanger, 'right'. So, it will not be here, here, here every where the same temperature, so that is why it is being plotted.

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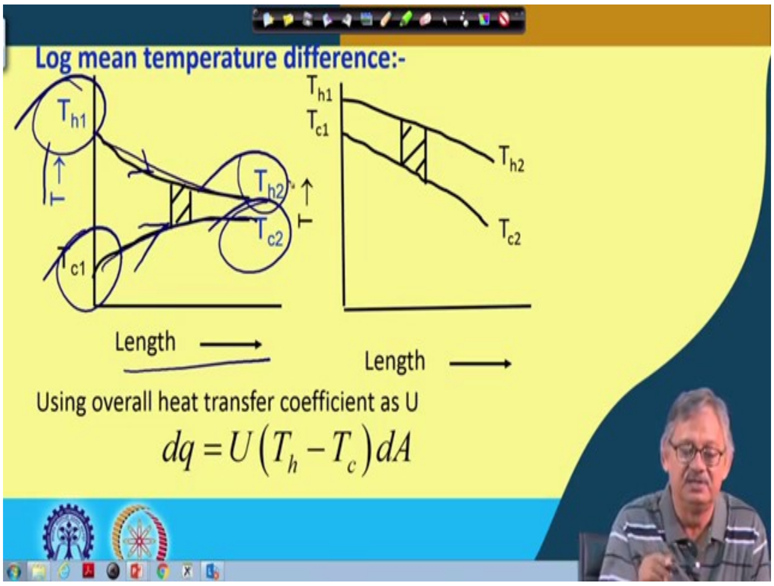

And for parallel and counter flow, we have shown this that we have fluid entering a hot fluid interning at T_{h1} and leaving at T_{h2} and the flow is parallel and the cold fluid is entering at T_{c1} and exiting at T_{c2}, 'right', so this is the direction of the flow. So, then if we plot T vs length, the curve which you will get is like this.

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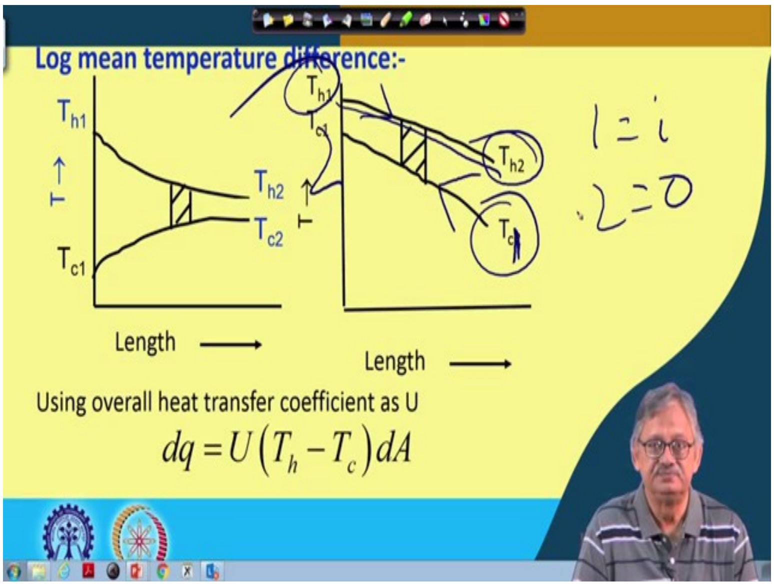

Whereas if you have a hot fluid is entering at T_{h1} like this and it is exiting at T_{h2} so, this is the direction of the flow and a cold fluid actually it should have been T_{c1}. So, by cut and paste it made the mistake and if it is T_{c2}, 'right', so in that case this is the flow direction, 'right'.

So, it is in a 1 and 2 we normally denote, 1 equal to inlet and 2 is equal to outlet, 'right'.

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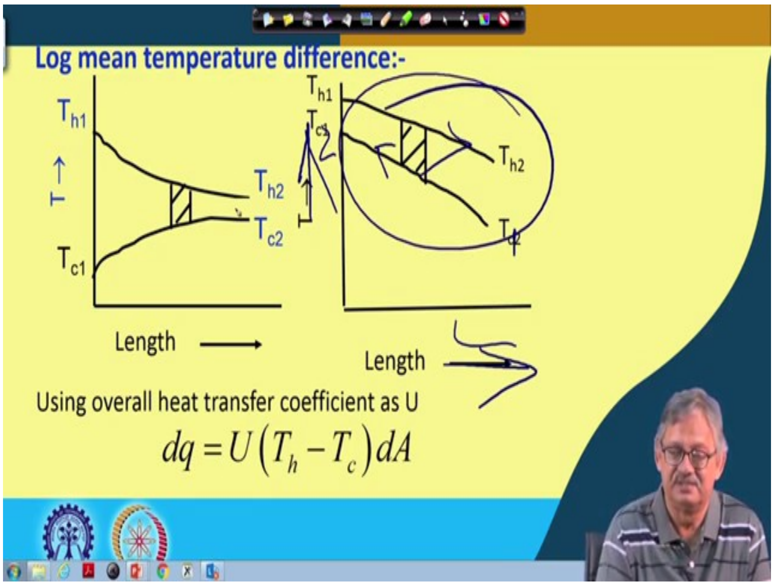

So, if two 1 and 2 is inlet and outlet, then it should be T_{c1} and it should be T_{c2} and the direction of flow should be like this, 'right'; and in that if we have a plot of T vs length, 'right', T vs L of the heat exchanger you have a plot like this, 'right'.

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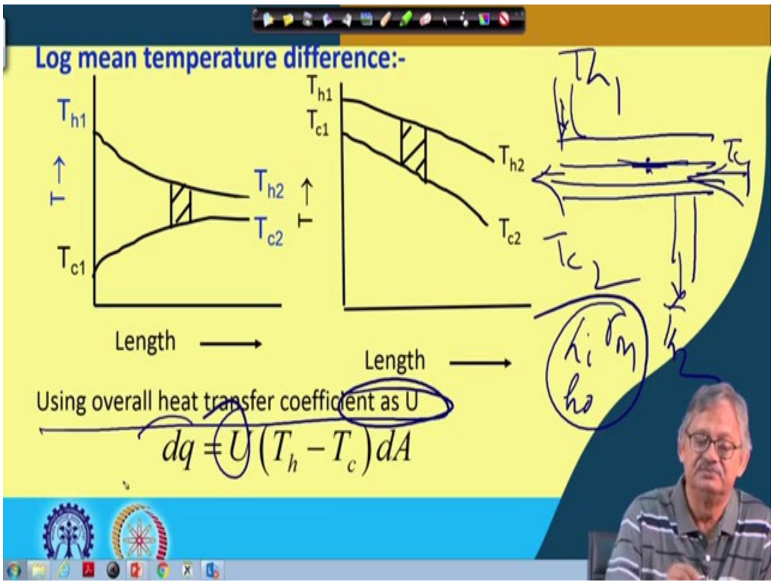

So, in all the cases we can use overall heat transfer coefficient U for the over why overall? Because in this heat exchanger which we had shown also earlier that one fluid is coming like that and another fluid is going away like this, 'right'. So, if this is that and if that be true, 'right', then they say this is T_{h1} and this is T_{h2} and this is T_{c1} and this is T_{c2}. So, what will happen we will have heat transfer coefficient between these two at this wall at this side wall at this side wall, 'right'. So, there will be ah_i there will be ah_o and there will be a resistance due to the metal, 'right' that is resistance due to the metal that also will have.

So, all this put together will make this U, 'right' of course, this overall heat transfer coefficient as of now we have not said we will come across afterwards. Now do with this preliminary of the overall heat transfer coefficient.

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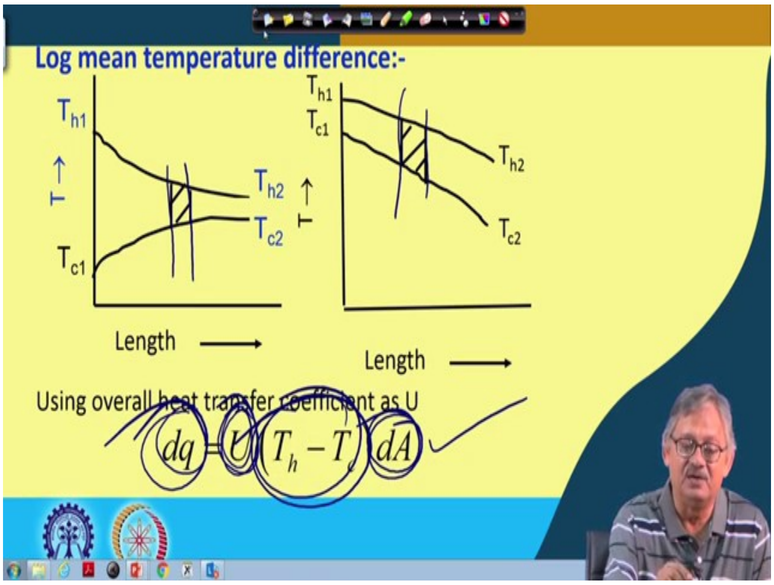

Let us tell the dq = U × (T_{hot} - T_{cold}) × dA this is what we have taken one section, 'right', this is what we have taken a section. So, dq = U × (T_h - T_c) × dA, 'right'.

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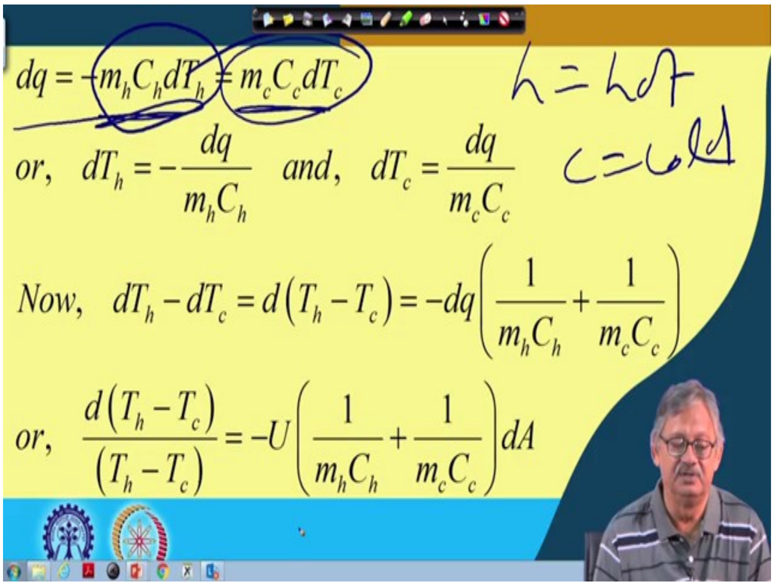

So that we can write and from there if we further analyze then we can say that, dq is nothing, but -m_h C_h dT_h and is also equal to m_c C_c dT_c, where h stands for hot and c stands for cold fluid, 'right'.

So, that m C dT that equation will also hold good that is equal to dq, 'right'.

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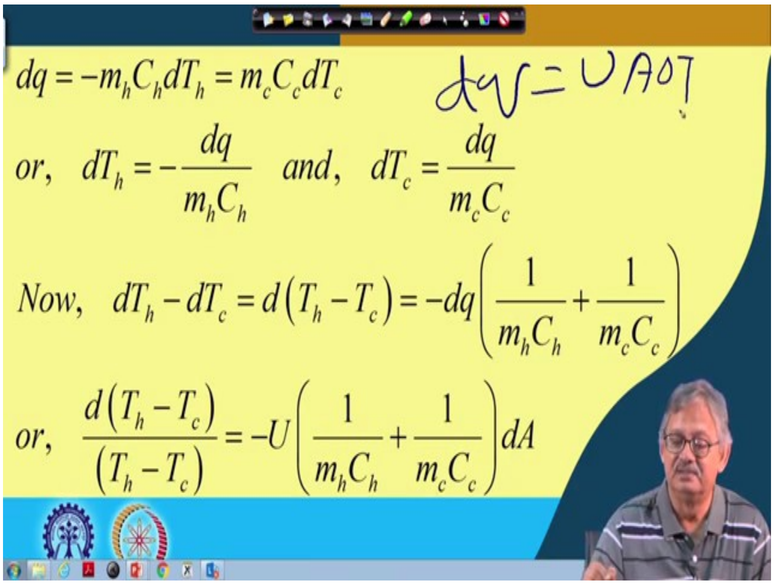

And earlier we have shown that dq who was equal to U A ΔT, 'right'.

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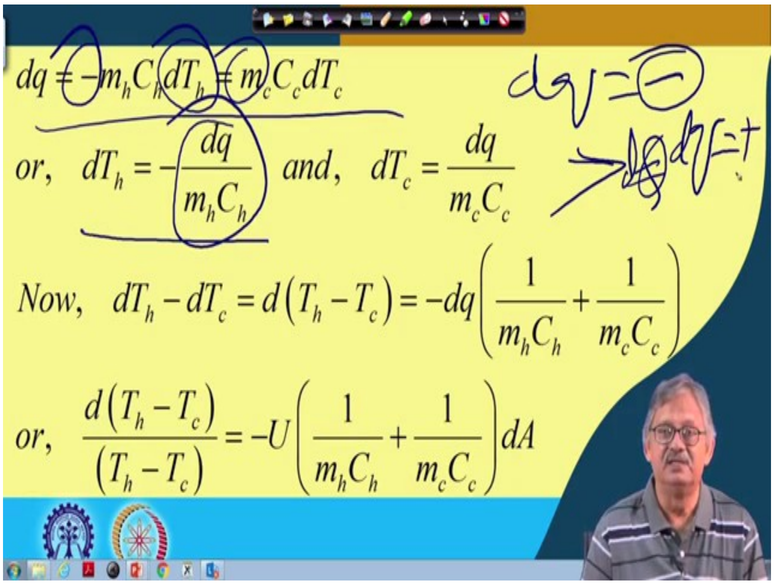

So, using these two relations we can we can write that d T_h from here is -dq over image why it is minus one is minus and the other is plus. That means, if one dq is negative means it is giving away the heat; and another is sorry another is receiving that and that is what is plus, 'right'.

So, who is having who is receiving and who is we were giving away this can be minus and plus, 'right'. By convention, we say that the hot fluid which is giving away that is dT_c and sorry that the hot fluid which is giving away is da dT_h normally with the negative and the cold fluid which is receiving, 'right', so that is with the plus then, $dT_h = -dq / m_h C_h$ $dT_c = dq / m_c C_c$, 'right'.

So, this is the heat capacity hot this is heat capacity cold fluid, 'right'. Then we can write $dT_h - dT_c$ that is that equal to $d(T_h - T_c)$ which can be written as -dq which we have already said there times $(1/ m_h C_h) + (1/ m_c C_c)$, 'right', $1/ m_c C_c$. So, we can rewrite this as $d(T_h - T_c)/(T_h - T_c)$, 'right' that this h and c; obviously, will be with the different inlet and outlet from that this is appearing to be identical it cannot be it cannot be made I mean taken out like this.

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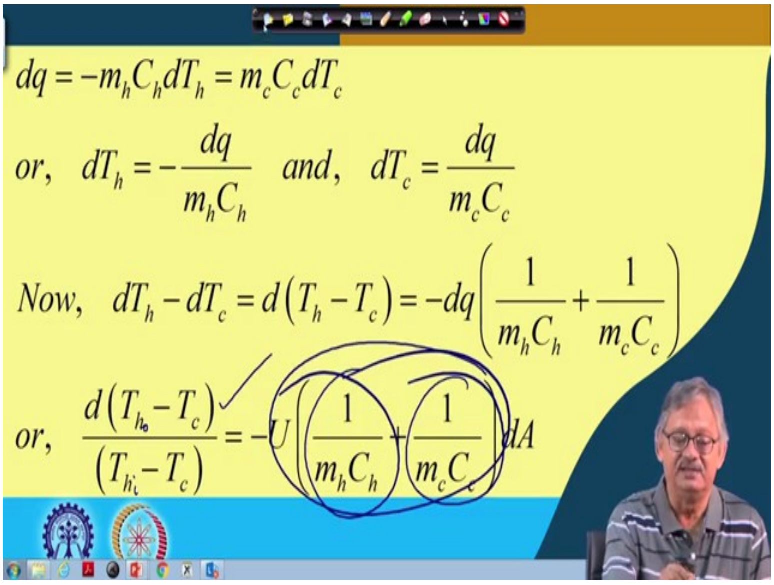

Because inherently there is one outlet inherently there is one inlet or one and two things are there. So, this is what we are writing, so that is equal to - $U_1(1 / m_h C_h + 1 / m_c C_c)$ dA, 'right'. So, today our time is up, so let us stop it now we will do in the next class subsequently, this analysis of the log mean temperature difference, 'right'. So, log mean temperature difference we have not completed in the next class we will do that the continuation of the log mean temperature difference.

Thank you.